EXHIBIT A

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Practical Welding Letter

PRACTICAL WELDING LETTER, Issue #010 -- Diffusion Bonding, Heat Resisting Filler, Heat Input,Preheat
June 01, 2004

We hope you will find this Letter interesting and useful.
Let us know what you think of it.

Practical Issues, Creative Solutions
Diffusion Bonding.

This publication brings to the readers **practical** answers to welding problems in an informal setting designed to be helpful and informative. We actively seek feedback to make it ever more useful and up to date. We encourage you to comment and to contribute your experience, if you think it may be useful to your fellow readers.

You are urged to pass-along this publication to your friends, if you like it, and if you want to help them. If you received this from a friend and if you like what you read, please subscribe free of charge and you will also receive a bonus book on
Practical HARDNESS TESTING Made Simple.
Click here.

Date: June 2004 - **Practical Welding Letter** - Issue No. 10

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1 - Introduction

While writing these lines we have passed the mark of 950 subscribers to **Practical Welding Letter**: although it is not an exceptional achievement it seems to indicate however that readers may be interested in what is published here. We urge you to propagate this easy and practical information source with your friends and colleagues.

If we had more feedback we would try to adjust the content to preferences and needs of our readers, but of course we can only ask for more involvement: this much we do, let us know how would you prefer this Letter. Click here.

In this issue we describe **Diffusion Bonding**, a typical solid state welding process that, especially when combined with Superplastic Forming, has interesting applications for titanium alloy aerospace components.

We report on a classic repair procedure using EBW (Electron Beam Welding) to **salvage** an expensive rejected finish machined aluminum alloy **casting housing**. This example could suggest other instances of possible EBW application.

Selecting the appropriate Filler Metal for **Heat Resisting** alloys may not be simple, due to the different types and base metals. We try to supply some basic knowledge and data on the subject.

As you can see in Site Update further down, we have added this month a new page to the Site on three old time Materials characterized by low melting point and exceptional corrosion resistance. Their joining is not without problems: it is helpful to know how to do it. Click here.

Heat Input needs some understanding, especially when its control is requested by applicable documents and Codes: we present here an article giving a short overview.

Other sections appear as usual. Your feedback is welcome. Click here.

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2 - Article: Diffusion Bonding

Diffusion Bonding is a solid state process that performs joining of metals and/or of ceramics without resorting to a liquid phase. We recall that a liquid is present when base material or filler metal is heated to melting temperature in fusion welding or brazing, or even in resistance welding.

We already know other solid state welding processes like forge welding, friction welding, ultrasonic welding, explosive welding, to name a few, but the process we are going to introduce here is unique as will be explained later on.

Diffusion bonding is obtained by applying heat, usually well below the melting

temperature of the metals, a static pressure to achieve intimate contact but not sufficient to produce gross deformation, and by allowing all the needed time to promote solid state diffusion, that is microscopic atomic movement to ensure complete metallurgical bond.

The diffusion bonding process, that is, the application of pressure and temperature to a joint surface for a prescribed period of time, is generally considered complete when cavities, present when the surfaces make their first contact, fully close at the interface.

The parameters are interdependent, in the sense that increasing one of them may permit decreasing another one or two. Surface roughness must be limited to minimum values, and cleanliness must be absolute. A protective atmosphere or vacuum may be required to prevent oxidation.

A minimum of deformation and the almost complete lack of residual stresses are characteristics of this process, except possibly if the two different metals being diffusion bonded together exhibit a large difference in the Coefficient of Thermal Expansion (CTE). This can cause strains to develop at the interface which can cause premature failure of the bond.

The principal mechanism for joint formation is solid-state diffusion. A diffusion aid (filler metal) may or may not be used. The products, finished to size, exhibit joint efficiencies approaching 100%.

The process is most commonly used for titanium in the aerospace industry and sometimes it is combined with Superplastic Forming (a special hot forming procedure). Ceramics can be diffusion bonded to themselves and to metals. Metals and alloys that exhibit very low solubility for interstitials (such as aluminum-, iron-, nickel-, and cobalt- base alloys) are not readily diffusion bondable. However practically any metal combination can he joined by diffusion bonding using suitable interlayers.

The more conventional form of diffusion bonding usually takes place in a uniaxial loading press. Pressure and heat can be applied by different means. More complex geometries than possible by the uniaxial process can be handled by Hot Isostatic Pressing (HIP) that involves the application of high-temperature, high-pressure argon gas to components. A hot isostatic press consists of a furnace within a gas pressure vessel. The components must be encapsulated in a sealed can to prevent the gas from entering the site of the bond.

Advantages of Diffusion Bonding:

- produces a product finished to size
- allows joining of different materials
- permits bonding of materials that cannot undergo fusion welding
- is a solid state process
- presents less shrinkage and stresses compared to other welding processes
- causes minimal deformation
- the process is highly automated and does not need skillful workforce

Limitations:

- costly equipment
- smooth surface finish requirements
- exceptional cleanliness needed
- protective atmosphere
- long time to completion
- relatively small components

- difference in CTE may need special attention
- pressure application can be a limiting factor

Although quite specialized and possibly costly, Diffusion Bonding can be an advantageous process for joining certain demanding aerospace parts.

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3 - How to do it well: EBW Repair of a rejected Casting.

Q: An expensive finish machined cast aluminum housing was rejected because an internal bore, located deep inside the part, at a great distance below the face of the top flange, was found oversize. How could it be salvaged by repair welding?

A: Regular welding would not be an acceptable solution. But Electron Beam Welding a spare bushing in place, although expensive, may salvage the cost already invested in the finished and rejected part.

By welding in place a spare sleeve the process has the potential:

- of precisely focusing the beam on top of the joint, despite the distance,
- of introducing the least amount of heat, avoiding damage to mechanical properties and preventing unacceptable distortion,
- of producing a thin and deep, precisely located weld seam,
- of avoiding the need for repeated heat treatment,
- of permitting thorough non destructive testing to qualify the repair,
- of being performed within the shortest turnaround time limiting the delay in delivering a replacement part.

(*Note*: The above is presented as Example 480 on page 541 of Metals Handbook Vol. 6, 8th Edition).

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4 - Filler Metals: Heat Resisting Alloys

An introduction to Heat Resisting Alloys and their weldability has been presented in the Site. Click here. We are going to present hereafter further details on weldability and filler metal selection.

Metals designed to resist to service stresses at elevated temperature are essentially complex alloys based upon Nickel, Cobalt, Iron suitably modified so as to present the required properties at high heat. Refractory metals are available for special applications.

Two general kinds of materials are available.

The alloys that are hardened by the presence of compounds (i.e. carbides) in **solid solution**, have basic mechanical properties that cannot be improved by applying Heat Treatment. Welding is performed in the annealed condition.

Otherwise different alloys are formulated so as to be able to modify their microstructure and mechanical properties through the successive phases of Heat Treatment consisting in **Solutioning and Precipitation Hardening** (or Aging). Welding is performed in the solution treated condition.

Many of the heat resisting alloys may be susceptible to **cracking** upon welding except if special procedures are implemented. Both types above have advantages and limitations and find useful niches of application in definite areas.

Either way welding processes risk to modify the composition and the condition of the materials presented for joining, so that a basic knowledge and understanding of the characteristics is required to use the welding procedures to the best advantage.

Furthermore upon being subjected to service temperatures for extended periods of time, some alloys may undergo modifications of microstructures making them susceptible to brittle fracturing without warning. Special procedures and controls are implemented to avoid this condition. Welding arc processes are currently employed for most of the alloys except that those processes characterized by elevated heat input are used only in certain definite cases.

In general **Gas Tungsten Arc Welding** (GTAW or Tig) with thoriated tungsten electrodes is the most widely used process for all the heat resisting alloys. Straight polarity, electrode negative, direct current is used for thinner sections. Argon is usually selected as shielding gas. For thicker sections **Gas Metal Arc Welding** (GMAW or Mig) is preferred, with reverse polarity, electrode positive.

Iron-Nickel-Chromium and Iron-Chromium-Nickel alloys are **Iron** base heat resisting alloys containing significant amounts of Chromium and Nickel. They are used in the range of 650 to 760 ^{O}C (1200 to 1400 ^{O}F). Preheat and postheat treatments, when necessary, should not exceed the working temperature range.

Strain hardening permits some improvement of mechanical properties through cold work deformation. Typical of this class are 16-25-6 and 19-9 DL alloys. These are easily joined by arc welding although the mechanical properties of base metal are going to be affected. Filler metals can be austenitic stainless steels, nickel base or alloys of the same composition as the base metal i.e.:
SAE AMS 5782 (19-9 W) - STEEL, CORROSION AND HEAT-RESISTANT, WELDING WIRE 20.5Cr - 9.0Ni -0.50Mo - 1.5W - 1.2Cb - 0.20Ti VACUUM INDUCTION MELTED

Welding anneals the material and reduces the mechanical properties (hardness and strength) around the welding seam. If performing preheating or postheating the temperature must be strictly monitored to avoid excessive reduction of mechanical properties.

Solid solution strengthened **iron** base alloys like **N-155** (Multimet) are easily welded by all arc processes but it is recommended to keep low heat input in order to limit grain growth and maintain weld ductility. No post weld heat treatment is usually required. Filler alloy of the same composition as the base metal is used:
SAE AMS 5794 - IRON ALLOY, CORROSION AND HEAT-RESISTANT, WELDING WIRE 31Fe - 21Cr- 20Ni - 20Co - 3.0Mo - 2.5W - 1.0Cb - 0.15N ANNEALED

A-286 is a **precipitation hardenable** iron base alloy. It is more difficult to weld, being sensitive to intergranular hot cracking in the weld seam and in the heat affected zone. To avoid or limit hot cracking, welding should be performed only in solution treated condition. Thin sheets do not require the complex procedures that are imperative for thicker sections. After welding the parts are again solution treated and aged. The standard filler metal for this alloy is:
SAE AMS 5804 - STEEL, CORROSION AND HEAT RESISTANT, WELDING WIRE 15Cr - 25.5Ni - 1.3Mo - 2.2Ti - 0.006B - 0.30V

Selection of filler metal may be open to consideration of the circumstances. It may be advisable to select a ductile material, like austenitic stainless steel or nickel alloy, to reduce weld stresses.
A popular selection is nickel base Hastelloy W:
SAE AMS 5786 - NICKEL ALLOY, CORROSION AND HEAT-RESISTANT, WELDING

WIRE 62.5Ni - 5.0C - 24.5Mo - 5.5Fe

Solid solution strengthened **Nickel** Alloys.

These alloys, besides being employed for elevated temperature applications, are widely used also in applications requiring resistance to corrosion. Although being mostly standardized they are commonly referred to through their commercial name.

Typical of this class are the following materials:

Hastelloy X, used mostly as sheet metal for hot components, is welded either with the same composition filler metal
SAE AMS 5798 - NICKEL ALLOY, CORROSION AND HEAT RESISTANT, WELDING WIRE 47.5Ni - 22Cr - 1.5Co - 9.0Mo - 0.60W - 18.5Fe
or, if necessary to avoid cracking, with the more ductile Hastelloy W,
SAE AMS 5786 - NICKEL ALLOY, CORROSION AND HEAT-RESISTANT, WELDING WIRE 62.5Ni - 5.0Cr - 24.5Mo - 5.5Fe

Inconel 600, employed in tubing for elevated temperature applications is welded with ERNiCr-3 (AWS A5.14) or Inconel 82.

Precipitation-Hardenable Nickel Alloys.

These materials are characterized by their distinctively high strength at room temperature through about 705 ^{0}C (1300 ^{0}F). Most of these alloys have good weldability in the annealed condition. Because of this, most are formed, machined, and welded in the annealed condition. They are then reannealed after welding, and further aged, to obtain the desired properties.

Typical of this class are the following materials:
Inconel 718, one of the most used alloys for gas turbines (see following note), is welded with ERNiFeCr-2 (AWS 5.14)
SAE AMS 5832 - NICKEL ALLOY, CORROSION AND HEAT RESISTANT, WELDING WIRE 52.5Ni - 19Cr - 3.0Mo - 5.1Cb - 0.90Ti - 0.50Al - 18Fe CONSUMABLE ELECTRODE OR VACUUM INDUCTION MELTED
Rene 41, is easily welded in sheet metal form with
SAE AMS 5800 - ALLOY, CORROSION AND HEAT RESISTANT, WELDING WIRE 54Ni - 19Cr - 11Co - 10Mo - 3.2Ti - 1.5Al - 0.006B
Waspaloy, mainly used as forging, is welded with
SAE AMS 5828 - NICKEL ALLOY, CORROSION AND HEAT RESISTANT, WELDING WIRE 57Ni - 19.5Cr - 13.5Co - 4.2Mo - 3.1Ti - 1.4Al - 0.006B VACUUM INDUCTION MELTED, SOLUTION HEAT TREATED

Note: - To improve the weldability of precipitation-hardenable alloys, niobium was substituted for large amounts of aluminum and titanium. The result was nickel-chromium-iron Alloy 718, which showed greatly improved resistance to postweld strain-age cracking . Thicknesses up to 3.2 mm (0.125 in.) could be welded in the aged condition and directly re-aged without cracking. This combination of very high mechanical properties and ease of fabricability contributed to give to this material an important place in the aerospace industry.

Little welding is performed in the aged condition if the weldment is to be re-heat treated or put in elevated-temperature service. Postweld strain-age cracking occurs in precipitation-hardenable alloys when cold work stresses, weld induced residual stresses, and the stress imparted by aging exceed the yield strength (and available ductility) of the material.

It must be remembered that certain alloys of this class, especially if cast with the

special procedures designated by Directional Solidification (DS) or Single Crystal (SX) cannot be welded at all without destroying the unique microstructures that guarantee the exceptional properties at high temperature. However under certain conditions, minor weld repairs were successfully performed on cast aged nickel alloys.

Cobalt base alloys

Cobalt-base alloys are not strengthened by a coherent, ordered precipitate. On the contrary they are a solid solution strengthened austenitic (fcc) matrix in which carbide-forming elements such as chromium, niobium and a supersaturating amount of carbon are present. These alloys precipitate complex carbides that contribute to the mechanical properties at elevated temperature. The softer and tougher compositions are used for high-temperature applications such as gas-turbine vanes and blades.

They generally have better weldability and thermal-fatigue resistance than nickel-base alloys. They are melted in air or argon, in contrast to nickel-base and iron-nickel-base alloys containing aluminum and titanium which must be processed by vacuum melting. Cobalt-base alloys however are more likely to precipitate undesirable brittle phases unless their composition is carefully balanced.

Typical of this class of wrought cobalt base alloys are:

HS-25 (also known as L-605), a long known alloy used in gas turbines, has also been used successfully in many industrial furnace applications. It is welded using SAE AMS 5796 - COBALT ALLOY, WELDING WIRE 52Co 20Cr 10Ni 15W

HS-188, which contains also lanthanum (a rare earth) for improved sulfidation and oxidation resistance, is the alloy of choice for combustor cans and afterburner liners in high-performance aircraft gas turbines. It is welded using
SAE AMS 5801 - COBALT ALLOY, CORROSION AND HEAT RESISTANT, WELDING WIRE 39Co - 22Cr - 22Ni - 14.5W - 0.07La

Full solutioning is preferred for relieving fabrication and welding stresses, and the aging treatment to provide carbides can be performed as usual in a furnace, or skipped, to be obtained in service. In either case the required properties should be achieved.

Mechanically Alloyed sheets and bars combine precipitation hardening and dispersion strengthening with yttrium oxide (Y_2O_3) to give these materials higher elevated-temperature stress-rupture strength.

These materials are produced by a combination of the mechanical forging of powder particles in a ball mill. Homogenization in the mill is followed by either hot rolling or extrusion. The form is then thermally treated at 1315 ^oC (2400 ^oF) to produce the exceptional hot strength characteristics. Unfortunately, making these materials weldable is difficult. Fusion welding produces a softened heat-affected zone (HAZ). In addition, it is not possible to obtain a weld that has properties similar to those of the alloys.

A wealth of technical information on properties and fabrication of Heat Resisting Alloys can be obtained at:
http://www.haynesintl.com/
http://www.inco.com/
http://www.cartech.com/

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5 - Online Press: recent Welding related Articles

Update: Titanium Specification Revised
This article details the additions and changes introduced into AWS A5.16 covering Titanium Filler metal.
http://www.aws.org/wj/2004/05/043/

The Influence of Various Hybrid Welding Parameters on Bead Geometry
Would you like to learn on Research performed on Gas Metal Arc augmented (or Hybrid) Laser Welding? This recent article shows you how it is done.
http://www.aws.org/wj/supplement/05-2004-RAYES-s.PDF

Mechanical testing - Tensile testing Part II
Welding procedure approval for tensile testing.
General information on testing required for approval of a butt welding procedure
http://www.twi.co.uk/j32k/protected/band_3/jk70.html

Tube Bending and cross section preforming
Preparation for welding: basic knowledge.
http://www.thefabricator.com/xp/Fabricator/Articles/Experts/Exp04/04web142.xml

Welding fume health hazards
Safe welding requires risk awareness and implementing of strict precautions.
http://www2.thefabricator.com/Articles/Fabricating_Exclusive.cfm?ID=851

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6 - Terms and Definitions Reminder

Diffusion: The spontaneous movement of atoms or molecules to new sites within a material. When occurring within the process named diffusion bonding, this movement of atoms across the interface tends to join the metals and eliminate voids.

Hot Isostatic Pressing: a process that subjects a component (casting, powder forging, etc.) to both elevated temperature and isostatic gas (argon) pressure in an autoclave. When castings are hot isostatically pressed, the simultaneous application of heat and pressure virtually eliminates internal voids and microporosity through a combination of plastic deformation, creep, and diffusion.

Intermittent weld is one where the continuity is broken by having stretches of weld bead separated by unwelded portions in a regular pattern.

Precipitation in metals is the separation of a new phase from solid or liquid solution, usually due to changing conditions of temperature, pressure, or time.

Precipitation hardening: is the hardening in metals caused by the precipitation of a constituent from a supersaturated solid solution. Also called age hardening or aging. The change in microstructure brings about an improvement of mechanical properties.

Solid-State Welding: a group of welding processes that join metals at temperatures essentially below the melting points of the base materials, and without the appearance of a liquid phase. It may or may not include addition of a filler metal. Pressure may or may not be applied to the joint.

Solid Solution: a single, solid, homogeneous crystalline phase containing two or more chemical species. With certain metals and solutes this structure presents improved properties.

Superplasticity: the ability of certain metals (notably aluminum- and titanium-base alloys) to develop extremely high tensile elongations (or plastic deformations) without cracking, at elevated temperatures and under controlled rates of strain.

Superplastic Forming (SPF): a strain rate sensitive sheet metal forming process that uses characteristics of materials exhibiting high tensile elongation. During superplastic forming at elevated temperature, gas pressure is imposed on a superplastic sheet, causing the material to form into the die configuration.

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7 - Article: Heat Input

This is a **hot** subject...
The thermal cycle associated with arc welding has a major influence on the microstructures affected by welding. The temperature distribution and the metallurgical changes occurring around a weld are necessarily influenced by a number of variables like:

- Heat Input of the process arc
- Starting temperature as influenced by Preheat
- Weld design, including shape and dimensions of the joint elements
- Thermal conductivity of base metal

The accepted formula for arc heat input is as follows:

H = E*I*60/S

Where:

- H is the heat input expressed in joules per unit length
- E is the arc Voltage in volts
- I is the arc Current in amperes
- S is the weld travel speed in unit length per minute
- * and / are the multiplication and the division symbols
- the factor 60 comes about because joule equals watt multiplied by second, to have compatible units on both sides of the formula.

The weld travel speed is possibly the parameter that can be modified more easily, so that any increase will reduce heat input. One must remember that the use of this formula has to be taken as an approximation because of the large heat losses unaccounted for. It may be useful, however, for comparison.

Its importance is due to the fact that some welding specifications limit heat input allowable, especially for the welding of quenched and tempered steels. Anyhow also the requirement is not a fixed number because of its dependence upon other welding conditions. It must therefore be interpreted according to the prevailing conditions. A higher heat input is permissible for increased thickness. It should be decreased for increasing preheat temperature.

As a determining factor, together with preheat temperature, for establishing the cooling rate, heat input is just one more parameter that has to be taken into account for controlling the outcome of the microstructures obtained.

For important applications series of tests should be implemented to verify the actual mechanical properties obtained with different heat inputs.

The decision if to implement and which Post Weld Heat Treatment (PWHT) will

depend upon results and requirements,

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8 - Site Updating

The Page of this Month, coming to enrich our Welding Advisers Site, is devoted to the joining problems of three old timers, three Materials known and employed since the dawn of civilization, namely Lead, Tin and Zinc.

Nothing glamorous about that, maybe, but if one recalls that quite a lot of spot welding is performed on tin or zinc coated steel for appliances and automobiles, it is sure that one should know how to do that.

You can read the new page by clicking here. Let us know of your preferences and needs, write us by e-mail. Click here.

A few AWS references are quoted in the page, containing important information on welding of metal coated steel.

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9 - Short Items

9.1 - Rolling-Elements **Bearing Failures** are usually catastrophic in that they can cause much secondary damage. For very important applications (i.e. aerospace) one should monitor at least periodically the condition of bearings by checking the lubricant, by vibration analysis and/or by acoustic emission techniques (i.e. listening to the sounds).

Proper filtered lubrication should be assured at all times, as it controls temperature and avoids metal to metal contact and as it limits wear to the minimum. Due to the high quality of modern vacuum melted bearing steels, failures are now only rarely traceable to material defects.

It should be remembered that a rolling-element bearing does not have an unlimited life. On the contrary a definite period of life is assigned to any bearing type, with a statistical component indicating the percentage of parts likely to fail within the indicated period.

If the major causes for premature failure are eliminated, like incorrect fitting, excessive preloading, overloading, improper lubrication, impact or vibration, contamination and stray electric currents, then the primary causes of failure will still remain: contact fatigue, wear and corrosion.

If it is important to learn why a bearing failed to meet its predicted life requirements, then the analysis of the accident should be entrusted to an individual experienced in this kind of investigations, to find out which unknown or uncontrolled factors may have caused the failure.

9.2 - **Beryllium Copper** alloys are precipitation hardenable. They can be formed in their soft, solutioned as received state, and then hardened through an aging heat treatment to obtain improved mechanical properties.

Soldering is specified when the service temperature is below about 150 ^{o}C (300 ^{o}F), where higher joining temperatures might damage components, and where electrical and thermal continuity require more strength than a mechanical bond can provide.

Brazing provides stronger, more heat-resistant joints than those formed by soldering. As brazing temperatures are higher than age-hardening levels, it is preferable that brazing be performed before aging. Special procedures are needed if brazing temperature approaches solutioning temperature.

Welding can be used for beryllium-copper including electron beam and laser welding, resistance welding for face-to-face sheet joining, gas tungsten arc welding for overlay or thick section joining, and friction welding for tubular sections.

Adhesive bonding is being used for beryllium-copper assemblies because of its low cost and good performance at temperatures up to 150 ^{O}C (300 ^{O}F).

9.3 - **High Speed Steels** are one kind of cutting tool materials. They derive their name from their faculty to retain useful hardness even at high machining speeds that generate elevated temperatures. They usually include, besides high carbon, also some Chromium and sizeable proportions of Tungsten and/or Molybdenum.

Flash welding and friction welding are used to weld low carbon steel shanks to high speed tool steel drill bits. Other welding processes can be employed for high speed tool steels within the general recommendations to be followed for tool steels in general. See the page, click here.

9.4 - **Joint Tracking** is a device that keeps the location of the welding process on the joint seam, either correcting occasional deviations or providing means to follow a winding path. The principle is adaptable to any welding process, but it is useful for high production ones like automatic or robotic applications.

Manual tracking is capable of minor corrections from straight line or circular path only for slow processes. Laser or electronic devices scan continuously the space in front of the weld and find the joint by detecting a change in a characteristic property: and then they provide a signal to correct in real time the position of the upcoming weld.

9.5 - **Kovar** is a proprietary nickel rich alloy used for making glass to metal seals, because its Coefficient of Thermal Expansion is the same as that of certain types of glass. This alloy is austenitic and does not harden when exposed to heat. Welding is possible by different methods, especially GTAW and Plasma, that should be tested to determine compatibility with application. Explosion welding of transition joint components as kovar-copper and kovar-aluminum is being currently performed. See commercial literature at http://www.cartech.com

9.6 - **Powder Metallurgy** is a method of manufacturing metallic objects that uses finely divided powders to be compacted in useful forms and then sintered at elevated temperature in a furnace, to develop thermal bonds to a solid consistence. The main advantage of P/M technology is the ability to fabricate economically high-quality, complex parts to close tolerances.

The process permits forming of objects from difficult to forge metals. Powders can be blended with oxides or other elements providing alloys in systems that could not be mixed otherwise, while controlling grain size and properties.

Important classes of materials produced in this way include cemented carbides (or hard metals) and cermets, originally developed for cutting tools, usually brazed to tool holders. Welding is possible with certain materials, using proper methods and precautions.

Modern gas turbine disks of exceptionally high properties are manufactured by

methods derived and developed from this technology.

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10 - Explorations: Beyond the Welder

The Society of Manufacturing Engineers
http://www.sme.org/

For Software from Academic and Research Institutions, see
http://www.openchannelfoundation.org/

International Tungsten Industry Association
http://www.itia.info

The Kakadu National Park can be visited at
http://www.deh.gov.au/parks/kakadu/

In a few days you may have (if you are fortunate enough to be located in a suitable place) the chance to observe personally a rare astronomical event. It is the Transit of Venus, the last of which occurred on December 6, 1882. Now it is going to happen on June 8, 2004. See the site at
http://www.transitofvenus.org/

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11 - Contributions: Preheat, Liability

11.1 - Readers have asked for indications on **Preheat** temperatures. We would like to suggest to interested people the following sources, available as wall charts or as desk charts, from the American Welding Society at
http://www.aws.org/cgi-bin/shop

PHSP - Suggested Filler Materials and Minimum Preheat Temperatures for welding Steel Pipe with Wall Thickness less than 3/4".

PHSS - Suggested Preheat Temperatures for welding Structural Steel Materials.

One can buy a Welding Preheat Calculator from Lincoln Electric at
https://ssl.lincolnelectric.com/lincoln/spmount/item.asp?prodnum=wc-8

11.2 - As you probably know, a page on **Liability** that appears in our Site can be seen by clicking here.
On a particular aspect of the same subject and on the responsibility of the person performing the investigation one can read an interesting article at
http://www.asminternational.org/pdf/spotlights/jfaplitigation.pdf
Called "Legal Issues involved in Failure Analysis" the article provides practical tips on the importance for the engineer "to be very aware of and sensitive to the legal issues that often surround the investigation of a failure".

11.3 - A kind reader pointed out an article reporting on the tragic death of a young boy following a practicing **Plasma Cutting** exercise in school. See
http://www.seven.com.au/news/topstories/83084

We have no other information on the tragic accident and we cannot comment on it: presumably an investigation team was appointed to look for causes and responsibilities.

We may only remind the AWS publication:
AWS F4.1: 1999 - Recommended Safe Practices for Preparation for Welding and

Cutting of Containers and Piping

"This standard informs the reader of the necessary safe practices to be followed in the cleaning and preparation for welding and cutting of containers and piping. It describes various methods for cleaning, including water, steam, hot chemical and mechanical, and techniques to be used for their proper preparation. 12 pages, published in 1999."

Note: Welding and Cutting may be dangerous. See:
ANSI Z49.1:1999 - Safety in Welding, Cutting and Allied Processes. Available also from AWS.

11.4 - Another correspondent proposed the idea of opening a **Forum** for discussion and questions. Let us have your comments. Click here.

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12 - Testimonials

From: sezgin.ozcan@btc.com.tr
To: feedback@welding-advisers.com
Date: 11 May 2004, 10:39:03 AM
Subject: RE: PRACTICAL WELDING LETTER, Issue #009 -- Explosion Welding, Filler Metal Comparison, Furnace Brazing

PRACTICAL WELDING LETTER, Issue #009 -- Explosion Welding, Filler Metal Comparison, Furnace Brazing

Thank you very much for this letter.

Interesting and useful section for me Post Weld Heat Treatment.

I had good information from this section.

Regards

From: pavainathan@rediffmail.com
To: support@welding-advisers.com
Date: 23 May 2004, 01:58:52 AM
Subject: Re: Hardness Book

Dear Elia Levi,
Thank you for your Hardness Book.
It is very useful to me.

regards,
Vaithiyanathan

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13 - Correspondence: a few Comments

13.1 - With the flooding invasion of unsolicited and unwanted e-mail messages called "spam", filling the inbox tray with junk and possibly with viruses and other objectionable items, we are compelled to undertake protective measures.

Therefore we wish to inform our readers of the following:

- We will not open attachments.

- Always include the subject of the message. It must be a clear indication of the content: if you write only "Hi" or leave it blank, chances are that it will be deleted without being looked at.
- If a legitimate question remains without answer for more than 48 hours, it is possible that the message was deleted without being read: if it is important send it again with a more pertinent subject, especially if your ID looks fancy and queer.

This is not to discourage your correspondence which is always welcomed, but only to try to protect the Site from all too real dangers.

13.2 - Occasionally the Hardness Book that we send to subscribers bounces back undelivered. We do not really understand why this should happen, as we just copy and paste your e-mail address as you send it to us. In some cases we were informed that the inbox of the recipient was full at the time. We cannot follow up with these cases. If this happens to you, first look at the size and fullness of your inbox and then ask us again to send the book to you.

13.3 - More often than not we are asked questions without being informed of the details of the case. The inquirer knows well what he/she is talking about, but we are left in the dark. No hints, no clues. How can we guess? That is why we prepared Form3, as an aid to remind the meaningful subjects that will shed light on the problem. Please use it. You will find it at
http://www.welding-advisers.com/subscription.html#Form3

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14 - Bulletin Board

14.1 - We are working on a number of new pages that we plan to add to the **Site** in the near future. Any requirements? Any preferences? We would like to be tuned to the needs of our Audience.

Let us know, write us your feedback. Click here.

14.2 - A Welding and Joining 2005 **Conference** has been announced.
It will be held in Tel Aviv, Israel from January 25-28, 2005
All details are available at
http://www.bgu.ac.il/me/convention/welding/welding2005.html

14.3 - We have been advised by our Site Host, **SiteSell.com** that new functionality has been just added to their already rich and helpful, unique SBI! toolkit. If you ever think of exploring what **You** could do on the Internet, not as a Visitor but as an **Entrepreneur**, a short visit will open your eyes.
Click here and here and here and here.

Good Luck. See you next time.

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